Olteţeanu, Ana-Maria - Towards an approach for computationally assisted creation of insight problems in the practical object domain, in Proceedings of the 5th International Workshop on "Computational Creativity, Concept Invention, and General Intelligence", editors Besold, T.;Kutz, O.; and Leon, C., Publications of the Institute of Cognitive Science, Osnabrück, 2016.

Towards an approach for the computationally assisted creation of insight problems in the practical object domain

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Abstract. Insight problems are creative solving problems used to assess creativity in human participants, and empirically study insight-related processes. However, not many such problems exist, and once a participant has been exposed to a particular problem, insight cannot be studied anymore in that context. This paper proposes an approach for creating more insight problems in the practical object uses domain. This approach uses cognitive understanding of some of the processes that take part in the solving of insight problems in this domain to create more such problems, and is amenable to computational implementation. The manual creation of a couple of such problems with this approach is described. Ways of making the approach computational are briefly discussed.

1 Introduction

Insight is an impressive phenomenon. Classical insight stories involve great artistic or scientific achievements – like the ones presenting (i) Archimedes shouting Eureka after having observed properties of water displacement that could help him solve the crown problem, (ii) Watson dreaming of spiral staircases before proposing the double helix structure of the DNA molecule and (iii) Kekulé's daydream of an Ouroboros snake eating its own tail, before coming up with the structure of the benzene molecule.

Insight, however, does not have to lead to big discoveries and involve historic level creativity [Boden, 2003]. Insight presupposes seeing an existing problem in a new way – a way in which it becomes solvable for the person seeing it. Insight is studied empirically using various types of insight problems created by humans. For example, [Dow and Mayer, 2004] have gathered a collection of problems which they split into the following categories: mathematical, spatial and verbal insight problems. A mathematical insight problem they mention is: *Which would be worth more, a pound of 10 dollar pure gold coins or half a pound of 20 dollar pure gold coins; or would they be worth the same? Explain your answer.* A spatial insight problem gives the participant Figure 1 and gives them the following task: *without lifting your pencil from the paper, show how you could join all 4 dots with 2 straight lines.* An example of a verbal insight problem from the same collection is the following: *The legendary runner Flash Fleetfoot was so fast that his friends said he could turn off the light switch and*

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jump into bed before the room got dark. On one occasion Flash proved he could do it. How?

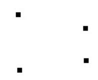

Fig. 1. The four dots problem

In this paper we will discuss a different (though at times overlapping) category of insight problems – problems which involve the practical use of daily objects, like the candle problem [Duncker, 1945] and the two strings problem [Maier, 1931][1]. This category generally involves objects and creative ways of thinking about objects, their relations and their affordances, as well as creative modes of re-representing problems concerning objects and practical physical goals.

As fascinating as some of them might be, insight problems generally stop being useful for the empirical study of the insight process if the participant has encountered them even once beforehand. If the problem was once encountered, the participant might simply remember what the solution was, rather than struggle to re-represent the problem, or experience a moment of sudden re-representation. The experiment sessions involving problems which are already known by the participants will thus be devoid of chances in gathering data on authentic insight and creative problem solving processes. Considering that one such problem can take a while to solve, and experimenters generally plan for only a few such problems per experimental session, not having enough new problems can result in lost experimental sessions, and the necessity of gathering more empirical datapoints, to substitute for the ones in which a participant was acquainted with one of the problems.

Within the practical object uses domain, not many insight problems exist, and some of them are quite old problems, created by the minds alike those of Maier and Duncker. A bigger dataset of such problems would benefit work focused on the understanding of human creative cognition, and could further find its application in creative problem solving work in robotics, and ambient intelligence. Therefore, defining an approach to create more such problems, an approach which could rely on computational means for problem creation assistance, would be useful for both cognitive psychologists and for AI. We already have some knowledge about the cognitive solving process of such problems. Creating them will benefit from such knowledge and bring about computational applications for it.

This paper thus sets out to define an approach to creating insight problems in the practical object uses domain, which is amenable to computational assistance and/or implementation. This approach is cognitive in nature, looking at

[1] [Dow and Mayer, 2004] classify both of these as spatial problems. In the following we will refer to such problems as insight problems in the practical object domain, as to differentiate them from spatial problems involving abstract patterns, like the one in Fig. 1.

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insight problems and their creation through the lens of insight related processes explored in a previous cognitive theoretical frameowork of creative problem solving [Olteţeanu, 2016,Olteţeanu, 2014]. In the following, existing classical insight problems will be analysed (Section 2); the approach will then be proposed (Section 3); the cases of applying that approach to the creation of two such problems will be explored (Section 4), and potential reliance on computational assistance in problem creation with existing or future tools will be discussed (Section 5).

2 Classical insight problems – analysis

In this section, three examples of classical insight problems are taken as case studies: (i) the candle problem, (ii) the two strings problem and (iii) the cardboard problem. These are analysed from the perspective of what makes them insight problems, and what processes could have been used to create them. Principles are then extracted for the creation of new problems. During this analysis, we will assume the following:

(a) there is a simple, non-creative (or much less creative) version of the problem which does not require insight;
(b) that by observing the steps and possible stumbling blocks of the solvers, while they receive the version of the problem which does require creative skill, we can extrapolate some processes which make a problem require creativity;
(c) that by using a variety of such interpolated processes and knowledge about cognitive problem solving, we can begin to create more such problems, even if we do not yet cover the entire variety of skills which can be tested through them.

Candle problem

The candle problem by [Duncker, 1945] is stated as follows: *You are given a candle, a box of thumbtacks and a book of matches* (see Fig. 2). *You are supposed to fix the lit candle unto the wall in a way that does not allow the wax to drip below.*

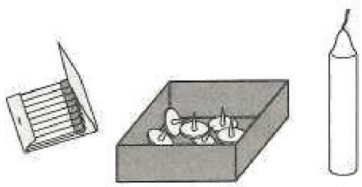

Fig. 2. The Candle problem

The candle problem is solved by taking out the thumbtacks from the box, and using the box as a container and platform for the candle, then fixing it (with thumbtacks) to the wall. The participants that get stuck while solving

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this problem generally have trouble seeing the box of thumbtacks as a possible container; this is sometimes helped if the box is empty.

Considering the types of processes involved in creative problem solving, including re-representation, one can attempt to reverse engineer them, and check whether this is conducive to the creation of similar problems. The following aspects can be synthesized from the candle problem to help the creation of new problems:

– Hiding an object which is necessary for a (non-creative) solution of the problem within a different other object. This aspect shows up in this problem by the fact that a candle holder, which would have made the problem straightforward, is not present. Such a candle holder needs to be re-represented out of existing problem objects - from the perspective of the problem creator, one can look at this process as one of hiding the candle holder in a different object (or set of objects) with a similar affordance. Such a similar affordance however needs to be inferred creatively, perhaps in a process similar to that used when solving the Alternative Uses Test [Guilford et al., 1978].
– Hiding the affordance of an object by emphasizing a different affordance and (optionally) having that affordance already taken up or in use. This aspect shows up in the candle problem by the act of adding the thumbtacks inside the thumbtack box[2]. Adding them near the box would have been a case for emphasizing the affordance of the box as a container. Adding them within the box is a case for having the affordance already in use. The purpose of the latter is, of course, to trigger and thus help study the functional fixedness bias.

Two strings problem

The two strings problem by [Maier, 1931] presents to the participant a situation like the one in Fig. 3. The participant is told: *A person is put in a room that has two strings hanging from the ceiling. The task is to tie the two strings together, but it is impossible to reach one string while holding the other.*

The two strings problem is solved by making a pendulum from one of the two strings and from a heavy object laid on the floor, like the pliers, then launching one of the strings in pendular motion, as to be able to have it come on its own towards one's hand. The participants that get stuck when solving this problem usually fail to see: (i) that the object can be set in motion on its own, rather than requiring the motion of the solver; (ii) that the object could be created, as this requires making it using other objects in the room.

Considering the steps involved in solving this problem, one can assume the process of creating such a problem involves the following aspects:

– As a general strategy, make objects which need to be used for the solution lose part of their affordances. A specific technique, observed in this case, is to enable affordance loss by removing affordance related parts of the object. The object will thus need reconstruction, while the parts themselves are less likely to trigger the same affordance. In the two strings problem, this is done by removing the saliency of the affordance of a pendulum to be mobile, through splitting the pendulum in

[2] It is the thumbtacks that make this a thumbtack box anyway, and one might be biased to look at this box as a special container for the thumbtacks because of the very description of the problem, which includes the verbal tag "thumbtack box".

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Fig. 3. The Two Strings problem

two parts. A self-based motion frame of reference might be emphasized in the verbal description of the problem (i.e. “it is impossible *to reach a string* while *holding the other*”), which focuses the participant on thinking of themselves, rather than other objects, as mobile.
- Split said object into parts and scatter the parts across the room. This is somewhat overlapping in the context of this problem with the principle above. However, the principle above can also involve removing solution-leading affordances of an object in different ways, by, for example, changing the frame of reference, representing the object in a space which makes the affordance less salient and constrains thinking about the object.
- Hide the object required to solve the problem (or object parts) within other objects. This principle is shared with the candle problem, with the added bonus that, here, not just objects but also parts of objects are exchanged for similarly affording objects. Here, the weight of the pendulum is hidden in heavy objects across the floor.
- Add objects that lead to other possible affordances, and thus other possible constructions – in this case the chair (getting up on the chair gets triggered), the nails (fixing one of the strings closer to the other by using the nails gets triggered).

Cardboard problem

The cardboard problem by [Duncker, 1945] is given as follows: *You are asked to help the experimenter attach this piece of cardboard to the loop on the ceiling. How do you proceed?* (our reconstruction of the depiction - Fig. 4).

This problem is solved by removing one of the paperclips, turning it around to make an S-shaped hook, then using one end of the hook to pierce the corner of the cardboard (the white paper corner can thus be kept in place too) and the other end to attach to the loop. Most people attempt to solve this problem using the nails and hammer on the table, various ways of standing the cardboard and attaching it with nails to the loop.

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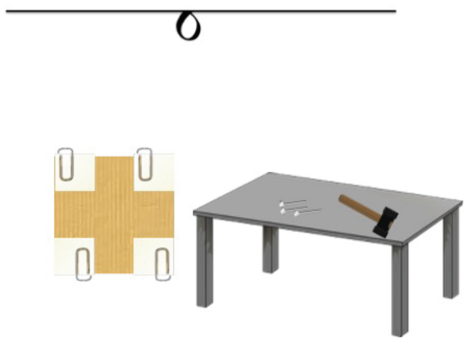

Fig. 4. The Cardboard problem

Creating problems like the cardboard problem could include the following aspects:

- Hiding part of the solving objects as parts of other objects. In this case, the paperclips are attached to the cardboard, and thus can be perceived as being part of it, thus part of the object which needs attaching to the loop, rather than of the tools which the attaching can be done with.
- Using one of the actions people would refrain from doing as part of the solution – i.e. destroying an existing object, disobeying rules or norms or arrangements perceived as implicit or unbreakable. In this case, not only the paperclips are used to hold together the white piece of paper at the corner of the cardboard (using them thus having the possible consequence of disassembling that part of the object), but also piercing the cardboard can be viewed as a way of damaging the cardboard irreversibly (in other problems, parts of objects can be pulled away by disassembling the object to pieces, however the object can also be reassembled).
- Have other objects with a similar affordance in the scene, as to interfere with finding the objects which would truly provide the solution. In the case of this problem, the affordance that nails and hammer have to fix something to a wall or a ceiling interferes with seeing the less salient affordance of the paperclip, setting the nails and hammer center stage as red herrings.

3 Approach

Various processes of solving seem necessary for the above described problems, and thus various principles of creating more such problems become apparent after this analysis. In this section, the extracted principles are discussed and summarized in an approach.

As mentioned in section 2, one of the parts of our analysis assumed that there is a simple, non-creative version of the problem, which does not require insight. For example, the candle problem would be in its simpler form if it would offer a candle holder as part of the existing objects, rather than the thumbtack box;

the two strings problem would be in its simpler form if one of the strings would be a pendulum already; the cardboard problem – if the paperclip was already twisted in the necessary S shape, or at least detached from the cardboard.

Consequently, this approach starts from the assumption that more creative problems can be constructed in the practical object domain, by taking simple day to day non-creative problems, considering one of their normal solutions, and then hiding the possibility of applying that solution from the solver via a set of re-representations and creative uses of objects (which then have to be traversed back by the solver) and problem templates (or sets of viable action plans).

A non-exhaustive list of some of the techniques that can thus be used in problem creation, in light of the previous case studies, includes:

(i) Diminishing the saliency of the objects required for the solution, by (a) putting them in a different context of affordances and possibly (b) having those affordances already allocated or used;
(ii) Hiding objects in a different form – by re-representing them as other objects which have similar properties and affordances (but for which said affordances might not be as salient as for the initial objects);
(iii) Decomposing the solution in different parts, and re-representing the parts in different structures or objects;
(iv) Representing needed parts as integrated parts of other objects;
(v) Using an object twice in the solution, with two different contexts of affordances. In this case, participants need to look at both sets of affordance contexts, to perceive the object in both of its potential roles, similar to being able to look at two ambiguous figures the perception of which can emerge from the same set of elements;
(vi) Adding to the problem other salient objects, the affordances of which might interfere with the solution;
(vii) Making use of natural or learned biases against breaking objects, crossing commonsense or common practice norms or aesthetic values.

Part of the techniques in this approach could be loosely summarized as the following (obj stands for object, aff for affordance, PT for problem template[3], sol for solution and $simProp$ for similar properties):

1. Embed in different affordance contexts:
   If $(obj_x \in PT_{sol}) \wedge \quad (\exists aff(obj_x) \neq aff_{sol}(obj_x) \vee$
   $\exists aff(obj_x, obj_k) \neq aff_{sol}(obj_x) \vee$
   $\exists PT_x | obj_x \in PT_x, aff(PT_x) \cap aff_{sol}) = 0)$
   then $display(aff(obj_x) | aff(obj_x) \neq aff_{sol}(obj_x) \vee$
   $display(aff(obj_x, obj_k)) \vee$
   $display(elementsOf(PT_x))$
2. Use creative object replacement:
   If $obj_x \in sol \wedge \quad \exists obj_a | simProp(obj_x, obj_a) \vee simProp(obj_x, partOf(obj_a))$
   Then $replace(obj_x, obj_a) \vee replace(obj_x, partOf(obj_a))$

[3] A problem template is a set of actions that will lead to a particular solution or affordance; such sets of actions are part of the commonsense knowledge of the subject. Creative use of problem templates is detailed in other works [Olteţeanu, 2014].

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3. Decompose object: $decompose(obj_x) = partsOf(obj_x)$
4. Represent needed parts as parts of other objects:
   If $obj_x \in PT_{sol} \wedge partOf(obj_b, obj_x) \wedge obj_b \notin problem \rightarrow replace(obj_x, obj_b)$
5. Double use:
   If $obj_x \in PT_{sol} \wedge obj_a \in PT_{sol} \wedge simProp(obj_x, obj_a) \rightarrow remove(obj_x)$
6. Adding other salient objects or templates:
   If $\exists aff_x | sim(aff_x, aff_{sol}) \wedge aff_x \notin PT_{sol} \wedge aff_x \in PT_x, PT_x \notin PT_{sol}$
   $show(aff_x) \vee show(obj_{k1}, obj_{k2}...obj_{kn} \in PT_x)$

4 Creating new insight problems – two cases

In this section, two problems that were created using the above principles are discussed. These are: (i) the blown away teddy problem and (ii) the Jack and Jill weight problem.

The blown away teddy problem

The blown away teddy problem presents the participant with the following task: *The wind blew your son's teddy bear from the clothesline into your neighbour's garden. The neighbour is in holidays and the fence is too high to climb. How can you retrieve the teddy?* Fig. 5 shows the problem.

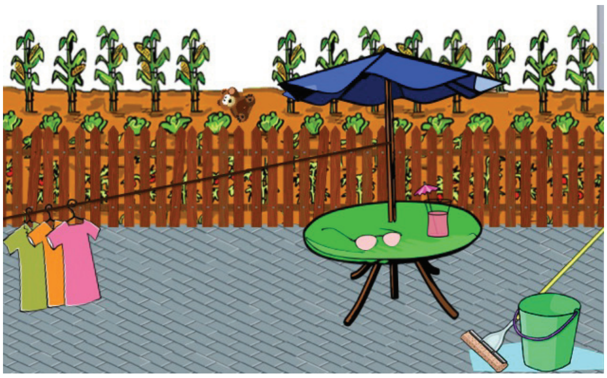

Fig. 5. The blown away teddy problem

This problem is solved by constructing a fishing rod, using the mop, the clothesline, and a clothes hanger attached to the clothesline.

The problem was constructed using the approach proposed in Section 3, in the following steps:

1. Start from a problem and an existing solution. The problem is that you need to obtain an object that is far away. The solution is to reach for the object.
2. Make solution creative. A fishing rod is used for fishing, but can have the alternative use of hooking something that is far away. The object replacement part of a system like OROC [Olteţeanu and Falomir, 2016] can be used to generate alternative uses.

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3. Decompose object into parts, so that it will require composition. The parts of the fishing rod used here are the pole, the string and the hook.
4. Hide the parts of the solution in other objects with different salient affordances, or in parts of other objects. The string is presented as a clothesline (one to one object mapping). The hook is presented as part of the clothes hanger (part of object). The pole is presented as part of the mop (part of object). The participant can also attempt to use the pole that is part of the umbrella, if the participant perceives this as movable.
5. Embed the replacement (or re-represented) objects in different contexts of affordances. The clothesline is presented holding clothes to dry, attached to the umbrella pole. The hangers have clothes on them, and are also partly obscured visually by the clothes (the part which provides the affordance conducive to the solution is, however, visible). The mop is presented next to the bucket and a water puddle, which emphasize its cleaning affordances.

Parts of the problem are also ambiguous – how tall the fence is, the height of the table, the distance to the teddy. The experimenter can let the participant attempt various strategies within this ambiguity, to observe various types of constructions created, paths pursued and forms of creative reasoning. Other constraints can then be set in place and communicated to the solver (e.g. the teddy is too far to be reached just using the mop) in order to observe new strategies at play.

This process can be summarized as the following:

1. Initial problem:
   (a) Starting condition: $faraway(subject, teddy)$.
   (b) Goal: $has(subject, teddy)$.
   (c) Solution: $reach(subject, teddy)$
   (d) Starting template: $reach(subject, teddy) \rightarrow has(subject, teddy)$
2. Creative version of a $reach$ template:
   $reach(subject, teddy) \rightarrow fish(fishing\ rod, teddy); beach, river, pool \notin problem$[4]
3. Decompose:
   $decompose(fishing\ rod) = (pole, string, hook)$
4. Creative replacement:
   (a) $creative\ replacement(string) = clothesline$
   (b) $creative\ replacement(pole) = mop\ handle$
   (c) $creative\ replacement(hook) = clothes\ hanger$
5. Embed in affordances or used affordances:
   (a) $embed(clothesline) \rightarrow show(attached(clothesline, pole), on(clothesline, clothes))$
   (b) $embed(mop\ handle) \rightarrow embed(mop) \rightarrow show(nextTo(mop, bucket))$
   $show(mopping(mop, water))$
   (c) $embed(clothes\ hanger) \rightarrow show(on(clothes\ hanger, clothes))$,
   $show(on(clothesline, clothes\ hanger))$

[4] This means we have to avoid a fishing related context for the rest of the scene, so the scene cannot be of a subset of scenes that might trigger fishing templates, like *beach* and *river*, nor scenes that are similar to them – like *pool*.

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Jack and Jill weight problem

The Jack and Jill weight problem presents to the participant a situation like the one displayed in Fig. 6. The participant is given the following task: *Jack and Jill are arguing about whom weighs more. What could they do to find out for certain?*

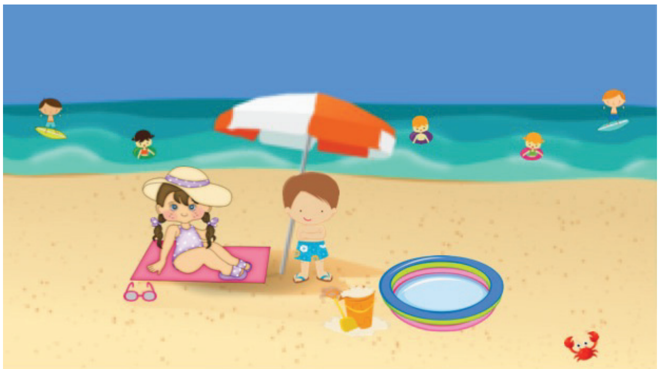

Fig. 6. The Jack and Jill weight problem

This problem is solved by making a seesaw from the bucket and a surfing board and placing Jack and Jill at opposite ends.

The problem was constructed using the following steps and techniques from the approach:

1. Start from a problem and an existing solution. The initial problem template was that balancing scales are used to measure weight.
2. Change the problem so that the solution would be creative – use seesaw instead of scales; put the problem in the beach setting (change of context to one which less affords thinking about weights and balancing scales, like a kitchen), and use of a different object with similar properties.
3. Split the object in various parts – the seesaw was split into a pivot and a support plank.
4. Hide the objects which form the solution by re-representing them as other objects or object parts – the plank was turned into a surfboard (also adaptation to the current context) and the pivot into a bucket (similar adaptation). Through the adaptation to context, both objects thus can be envisaged as belonging to a normal beach scene, rather than triggering the attention of the participant as objects that have especially been added to the beach context because they are part of the solution.
5. Hide the objects in different contexts of affordances and possibly have those affordances be already in use – the bucket is turned with its side up, and in its container affordance (full of sand); the surfboard is being surfed on, and quite far away, which makes it visually less salient. Some participants might also have social qualms with solution steps that involve asking for an object which is being currently used and belongs to someone else.

6. Add objects which act as red herrings, providing a similar affordance as the one necessary for solving the problem, thus getting the participant started on a different track – the small plastic swimming pool can get the participant started in this case on an Archimede's principle template.

This process can be summarized as the following:

1. Initial problem defined:
   (a) Starting condition: $unknownWeight(x, y)$.
   (b) Goal: $findWeightDifference(x, y)$.
   (c) Solution: $balance(x, y)$
   (d) Starting template: $balance(x, y) \to findWeightDifference(x, y)$
2. Creatively change the initial template (problem+solution):
   $balance(x, y) \to seesaw(person_x, person_y), PT_x \neq kitchen$
3. Decompose:
   $decompose(seesaw) = (pivot, support\ plank)$
4. Creative replacement:
   (a) $creative\ replacement(pivot) = bucket$
   (b) $creative\ replacement(plank) = surfboard$
5. Embed in affordances or used affordances:
   (a) $embed(bucket) \to show(in(bucket, sand), near(bucket, toy\ spade))$[5]
   (b) $embed(surfboard) \to show(on(water, surfboard)), on(surfboard, surfer))$
6. Addition of red herring objects:
   $sim(measure\ weight, measure\ volume) \wedge measure\ volume \notin PT_{sol} \wedge$
   $measure\ volume \in PT_{Archimedes} \wedge bathtub \in PT_{Archimedes} \wedge$
   $sim(bathtub, pool\ with\ water) \to show(pool\ with\ water)$

An extra point can be made about embedding the entire problem in a new contextual setting. The problem template of balance is in this case creatively transformed to a template about seesaws, and then imported in the contextual setting of a beach. The beach location could have been chosen as a consequence of having already picked one of the two replacement objects for the seesaw parts – the surfboard. Laying this object in its own contextual setting made the natural choice a beach, and the replacement for the second object, which did not have that many constraining properties, could be fixed to another object in the same setting – the bucket.

5 Discussion – towards a computational approach

As shown in the above test cases: (i) insight problems in the practical uses of objects domain can be analysed from the cognitive perspective of re-representation, and creative inference, (ii) such principles can be put together in an approach towards creating more insight problems and (iii) the approach can be used to create more insight problems in the specified domain.

[5] The PT of using a bucket to dig and play with sand is supported by the neighborhood of objects such a spade, a sand castle, etc.

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This approach might not reflect a reverse engineering of all the types of insight processes, or might not yet result in all the types of problems that can be created in the domain. However, starting from creating some such problems and evaluating them with human participants will have the impact of understanding and controlling the process of creating insight problems more thoroughly, and thus, in the future, providing a wider database of problems, based perhaps on a wider array of processes.

Creating insight problems might seem like a lofty computational pursuit. However, as shown above, the processes implied by this approach are substantial enough to allow for formalization. An interesting next step would be to tackle the issue using computational assistance when creating such problems. Part of the tools needed for such an approach already exist, at least in prototype form.

Take item (ii) of the list of techniques provided by the approach here – hiding objects in a different form – by replacing them with objects which have similar properties and affordances (but for which solution related affordances might not be as salient as for the initial objects). The creative object replacement (OR) part of OROC [Olteţeanu and Falomir, 2016] can be used to generate items from the practical objects domain which have similar affordances as the initial items. OROC makes creative inferences about new affordances of known objects, based on the similarity between said objects to other objects on shape and material properties. The object composition (OC) part of the same system can in part take care of items (iii) and (iv) on the list, specifically by decomposing various objects which are part of the solution in object parts, then finding similar objects with similar properties (OR) in its knowledge base; these objects, or the ones they are part of, can be used to substitute initial objects which are a salient part of the solution.

Other parts of this approach, like (i), (v) and creative transfer of a simple problem can be based on OROC knowledge, but also require knowledge of problem templates. Such knowledge should include contexts of affordances in which various objects get engaged, functional subsets of objects which are employed in such templates, qualitative or quantitative measures of similarity of template affordance, and some measure for when templates achieve similar but not quite the same results – thus interfering with the human judgement because of the similarity component, but not being able to help participants solve the problem.

In conclusion, a few case studies of classical insight problems have been analysed, in order to extract a set of principles which can be used in the creation of new insight problems. A non-exhaustive approach towards mechanisms that can be used to create such problems, and that is amenable to computational implementation has been proposed. Then, the applicability of the approach has been analysed, by describing it in the context of two newly created insight problems. Some existing tools that can be used to assist with this process have been briefly discussed. As future work, we plan to start (i) implementing this approach and/or relying on computational assistance, and (ii) experiment with problem template acquisition, problem template transfer and creative replacement of problem templates.

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